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APPLICATION

FOR

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TITLE: DATA COLLECTOR WITH INTEGRAL SPEED SENSOR

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SPECIFICATION

DATA COLLECTOR WITH INTEGRAL SPEED SENSOR

Field of the Invention

The invention relates to collection and analysis of data for the
5 purposes of predictive maintenance.

Background of the Invention

There are many well known methods for collecting data for
performing predictive maintenance. Typically, in these methods a vibration
sensor such as a piezoelectric accelerometer is mechanically coupled to the
10 machine to be monitored. The vibration sensor collects vibrations from the
machine and converts these vibration to an electrical signal. The electrical
signal is processed by suitable signal processing and converted from analog to
digital form. The resulting digital signal is stored for later analysis.

Often it is necessary to evaluate the rotational speed of the
15 machine being monitored as part of the collection of vibration data. This is
often done through the use of a tachometer mounted to the machine or used

with the machine. A difficulty arises when no such tachometer is available. To deal with this situation, a portable tachometer must be used. U.S. Patent 5,059,901, owned by the assignee of the present application, and incorporated by reference herein in its entirety, describes one such portable tachometer.

5 The tachometer described in U.S. Patent 5,059,901 utilizes laser light to measure rotational speed of a machine. Specifically, a laser provides a beam of light, visible even under extremely bright ambient light conditions, to be used to measure the rotational speed of a rotating device from greater distances than previously possible. A diverging beam of laser light is collimated and
10 transmitted to a rotating body the RPM of which is to be measured. The rotating body includes a reflective strip or strips, so that during rotation the reflection of the beam is modulated. The modulated reflected light is received by the tachometer where it is focused onto a photodetector, which converts it into an electrical signal representative of the speed of the rotating body.

15 Analysis of a vibration signal from a machine typically involves one or both of (1) comparing that signal to previously collected signals to identify an variations that would be indicative of machine wear and possible impending failure, and (2) forming a frequency spectrum of the vibration signal and evaluating this spectrum for patterns indicative of potential failures.

20 Typically these operations are performed through the use of a data collector. A data collector includes analog signal processing electronics for receiving a

vibration signal and conditioning that signal, and an analog to digital converter for digitally sampling the analog signal so that it may be stored and analyzed.

Often a first vibration signal is used as a trigger or reference signal in connection with the collection of a second vibration signal, in which case two

5 accelerometers are used. Signal analysis may be performed using the data collector itself or by uploading collected and digitized signals from the data collector to a host computer where signal analysis is performed.

It will be appreciated that a data collector is typically portable, to facilitate its use in an industrial environment. A technician will carry the
10 data collector to the machines being monitored and then collect vibration and speed data at each machine. Unfortunately, however, when a laser tachometer is being used, the collected devices may be cumbersome to handle, as the laser tachometer must be held in-hand and sighted to the location of the rotating body being used as the tachometer reference. At the same time, one or two
15 accelerometers must be held or mounted to the machine to collect vibrations.

And, of course, the data collector itself must be held or placed on a surface where its display can be read and keys can be reached, during this process.

Thus, the use of all of these features in a portable data collector is an inconvenient process and requires complex manipulation of the collector and
20 its various attachments.

Accordingly, there is a need for a data collector and data collection method utilizing a laser tachometer that is more convenient and less complex and thus can be more readily used in a wide range of applications.

Summary of the Invention

5 In accordance with principles of the present invention, this need is met by a data collector having an integrated tachometer device.

Specifically, a data collector in accordance with principles of the present invention comprises a housing, a vibration signal input on the housing for receiving a vibration signal to be digitized, an optical system in the housing receiving light from outside said housing to be converted to a digital
10 signal, and a digital signal processing circuit receiving, storing or processing the digitized vibration signal and/or the digital signal converted from said received light, for the purpose of predictive maintenance.

In the specific embodiment disclosed herein, a light source
15 emits light from the housing through an aperture, for reflection and return to the optical system. The light is generated by a laser diode, collimated by a collimating lens. A filter is positioned between the housing aperture and the PIN diode, to filter light other than at a wavelength of the light source. The reflected light is detected by a PIN diode. Reflected light is directed to the PIN
20 diode by a beam splitter in the optical system. A threshold comparator compares current flow in the PIN diode to a threshold, and produces a digital

signal to the digital signal processing circuit when said threshold is exceeded,
so that the processing circuit may compute a rate of rotation of a moving
element in response to timing of the digital signal from said threshold
comparator, thus forming a laser tachometer. Rotational speed information
5 generated from the integrated tachometer, may thus be used by the data
collector as part of analyzing or storing the digitized vibration signal.

The housing of the data collector in the disclosed embodiment
also holds a display and input keys, and is sized to fit in a single hand of an
operator. As a consequence, an operator may use the same hand for holding
10 and controlling the data collector, and for holding the laser light source for the
laser tachometer. This frees a hand for holding an accelerometer or for other
purposes. Use of a data collector with an integrated laser tachometer, in
accordance with principles of the present invention, is thus substantially more
convenient than using a data collector with a separate, nonintegrated laser
15 tachometer attachment. The invention thus provides substantial improvement
in the process of data collection over the prior art.

The above and other objects and advantages of the present
invention shall be made apparent from the accompanying drawings and the
description thereof.

Brief Description of the Drawing

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with a general description of the invention given above, and the
5 detailed description of the embodiments given below, serve to explain the principles of the invention.

Fig. 1 is an illustration of a palmtop data collector including an integrated laser tachometer;

Fig. 2 is a block diagram of the data collector of Fig. 1 and the
10 laser tachometer system included therein;

Fig. 3 is a circuit diagram of the laser detector included in the data collector of Fig. 2.

Detailed Description of Specific Embodiments

Referring to Fig. 1, a data collector 10 in accordance with
15 principles of the present invention is sized and designed for hand held operation. Data collector 10 will be referred to as a palmtop data collector for the reason that it is sized for holding in a single hand. The data collector includes a microprocessor and software used by the operator to collect data and transfer the collected data to a host PC. To control operations of the data
20 collector, the operator utilizes a keypad 12 comprising a plurality of alpha numeric keys, as well as soft keys 13, and an STORE key 14. The soft keys 13

are positioned adjacent to areas of a display 16 so that the user may be presented with functions assigned to the soft keys 13 that can be changed for different operations of the palm top data collector 10. The STORE key 14 may be used in connection with the keys of the keypad 12 or the soft keys 13 to indicate acceptance of identified values or settings that are selected with those other keys. The STORE key is replicated on both sides of the housing of the palm top data collector, for the convenience of left- and right-handed users. Utilizing this user interface, an operator may activate the palm top data collector to collect data from machinery to be monitored, as is known in the art.

Palmtop data collector 10 includes a plurality of connectors and other elements on its top end. These include a pair of accelerometer jacks 18 for connection to dual accelerometers for collecting vibration data from machinery being monitored. Vibration data collected through the accelerometer jacks 18 is stored within the palmtop data collector 10 for analysis and/or later delivery to a host computer system. The palmtop data collector 10 is connectable to host computer system utilizing a RS232 serial port 20, which may be coupled to the serial port of a host computer utilizing a standard RS232 serial cable. The palm top data collector 10 includes hardware for initiating a RS232 connection to a host computer and for transferring stored vibration data collected from accelerometers to the host

computer. The data uploaded to the host computer may then be analyzed in detail and compared with historic data previously uploaded to the host computer, as is known in the art.

The top panel of palm top data collector 10 further includes a power and trigger signal connector jack 22 for connection to an external trigger signal, such as one created by an optical detector on a rotating machine. This jack may also be used for connection to an external power supply whenever electrical power is available, such as when the palm top data collector 10 is being connected to a host computer to transfer collected vibration data. Power/trigger jack 22, when connected to a power terminal, receives DC or AC power to power the circuits within palm top data collector 10. AC or DC power for connection to power jack 22 may be generated utilizing a wall converter of conventional type as are commercially available.

A final feature of the top surface of the data collector 10 is a window or aperture 24 through which a tachometer laser beam is emitted for performing tachometer functions in accordance with the principles of the present invention. As is described in further detailed below, the circuitry for generating a laser beam and for receiving this laser beam and converting it to a tachometer signal is incorporated within the electronics of the palm top data collector 10. The laser beam generated by data collector 10 is emitted from window 24 as is illustrated at 26. The laser beam impinges upon the rotating

element of the machinery to be monitored to detect passage of reflective strips that are indicative of machinery rotation. The resulting reflection signal is detected and converted into a rotation speed within the circuitry of the palm top data collector 10.

5 Referring now to Fig. 2, the electrical block diagram of a palm top data collector in accordance with the principles of the present invention can be explained. The components of this device include a diode driver circuit 30 for driving a laser diode 32 for producing laser tachometer signals. The diode driver circuit 30 supplies energizing voltage through line 31 under
10 control of a central processing unit 40, when laser tachometer functions of the palm top data collector have been enabled. The energizing voltage supplied through line 31 causes laser diode 32 to emit light. Diode driver circuit 30 also provides power control signals to a laser detector circuit 34 so that laser detector circuit 34, when energized, may detect laser light reflected from the
15 rotating body to a photo diode 36. Light detected by photo diode 36 is converted to an electrical signal by laser detector circuit 34 and then forwarded to central processing unit 40.

The laser beam is processed by an optical system including an collimating lens 42, beam splitter 44, diachroic filter 46, a focusing lens 48
20 and a PIN photo diode 36. The optical components identified above are formed in an opening of the main housing of the palm top data collector. The

axis of the optical system is directed through the window or aperture 24 at which the diachroic filter 46 is mounted. The inner surface of the housing where the optical system is positioned (hereafter known as the optical system housing) must be rendered nonreflective by being coated with a nonreflective substance.

Within the optical system housing, a beam splitter 19 is mounted at a 45° angle to the axis of the optical system. Collimating lens 42 is rigidly fixed within the optical housing, at an end proximate the laser light generating diode 32. Collimating lens 42 is positioned in front of laser diode 32 such that lens 42 intercepts and focuses a diverging beam 50 of light emitted by diode 32 into a collimated beam 36. The beam follows the axis of the optical system and is emitted from the opening in the palmtop data collector housing. Collimating lens 42 is rigidly fixed using a mechanical means permitting the position of the lens to be adjusted relative to the emitting surface of laser diode 32 to fix the focal point of beam 26. Beam 26 is focused at infinity to produce a collimated beam emerging from the palmtop data collector.

The operating range of the palm top data collector is approximately 2 meters, using a class 2 laser. Although the device utilizes a single lens for collimation of the beam 50, the ultimate range and

performance of the device can be enhanced by using a lens or compound lens assembly of different parameters.

Ordering beam splitter 19 is mounted at a 45° interface within the optical housing, so as to extend diagonally across the axis of the beam 26.

5 The dielectric coated beam splitter 44 provides for a 50/50 ratio of the transmitted to reflected electromagnetic beam energy incident upon it. The reflected portion of such an incident beam will be reflected as a substantially 90° angle from the axis of the beam 26.

10 Beam 26 is incident at an angle of 45° upon a first face of the beam splitter 44. A 50% portion of beam 26 is reflected by beam splitter 44 and absorbed in a nonreflective coating of the optical housing. The remaining 50% of beam 26 is passed to a diachroic spectro line filter 28. Filter 28, is a standard hardware item, selected for transparency of at least 60% within the electromagnetic wavelength of the laser diodes operating frequency, in one
15 example, a wavelength of 670 nm. The function of filter 28 is to prevent the entrance of ambient electromagnetic energy with wavelengths other than 670 nm, will simultaneously passing at least 60% of the selected wavelength embodied in the reflected beam.

It will be appreciated by those skilled in the art that the device
20 of the present invention could be operated without a diachroic spectral line filter 46 in cases where noise immunity is of limited importance. Also, laser

diode 32 could be modulated and synchronous deflection techniques could be employed within laser detector circuit 34 to provide high ambient noise immunity in either in conjunction with or without diachroic spectral line filter 46.

5 Light passing through diachroic spectral line filter 46 will continue, and impinge upon the rotating body 52 for which rotational speed is to be measured. The fact that laser beam 26 is composed of coherent red visible light enhances the target ability of the device, in that the laser beam may be viewed incident upon the surface of the rotating body 52.

10 As a uniform body 52 would not provide a point of reference for counting revolutions, a device such as 54, which can be a strip of reflecting tape, for example, can be affixed to the body to provide regular strong reflections of the incoming laser beam 26. It should be noted, member 52 may possess variation in reflectivity of its surface, whether intentional or intended,
15 that can be used as reference point for counting revolutions; in such a circumstance, it may not be necessary to introduce a reflective element 54.

Typically, when beam 26 is instant upon the surface of a rotating member 52, at the point where reflective element 54 is affixed thereto, beam 26 will be reflected through a 180° angle. The beam so reflected will be
20 referred to as a beam 56. The intensity of the reflected beam 56 is pulsatingly modulated as the reflective element 54 moves into and out of position to

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reflect the incident beam 26. Typically, a substantially larger quantity of incident light is reflected when reflective element 54 is positioned as shown in Fig. 2 to reflect the incident beam 26. Thus, passage of the reflective element 54 passed the location of incident beam 26 can be detected by a substantially
5 larger quantity of reflective light. At least 60% of the reflected beam 56 passes through filter 28. The reflected beam 56 then impinges upon a second face of 50/50 beam splitter 44 where 50% of beam 56 passes through beam splitter 44 and is absorbed by the interior walls of the housing. The remaining 50% of the beam 56 is reflected of angle of 90°, at which point the still
10 collimated reflected beam 56 impinges on focusing lens 48 and is converted to a converging beam 58, the focal point of which is adjusted to be coplanar with the active light sensing element of a PIN photo diode 36.

PIN photo diode 36 is permanently fixed, by mechanical means such as an adhesive, and positioned to receive light focused by focusing lens
15 48. PIN photo diode 36 has a peak spectral response at or near the frequency of light produced by laser diode 32, to match its response to the coherent light emitted by laser diode 32. For example, where laser diode 32 emits red light at a red length of 670 nm, PIN photo diode 36 is selected to have a peak spectrum response at or near 670 nm. In the event of the use of laser diode
20 which emits a different wavelength of coherent light, a photo diode having a spectrum response to match will need to be selected accordingly. For

analog to digital converter 74 coupled to those analog interface circuits 72.

The output of analog to digital converters 74 is collected by central processing unit 40 and stored for later delivery to a host computer and/or analysis.

Central processing unit 40 utilizes a memory 76, which may include a solid state memory or a hard drive or a floppy drive memory, to store data collected from accelerometer 70 as well as tachometer readings obtained through laser detector 34. Data stored in memory 76 may be later output to a host computer via an RS232 serial interface 78 and the external RS232 connector 20 as discussed above.

An operator controls the operation of central processing unit 40 through key strokes at input keys 12, 13 and 14 as noted above. Feedback to an operator is provided by a display panel 16 as noted above.

Central processing unit 40 receives trigger signals on a line 80 that are externally generated at connector 22 via a power trigger interface circuit 82. Interface circuit 82 may also receive external power which is supplied to a power supply circuit 84. Power supply circuit 84 delivers supply voltages on lines 86 to other components of the palm top data collector 10. When a power supply is not connected to connector 22, power to palm top data collector 10 may be obtained from a battery 88 connected to power supply circuit 84 and included within the housing of palm top data collector 10.

Referring to Fig. 3, the laser detector circuit 34 for detecting

light impinging upon PIN photo diode 36 can be explained. Photo diode 36 takes the form of the base-emitter junction of an opto-transistor. Carriers are injected into the base of opto-transistor 36 in proportion to light incident upon

5 photo diode 36, thus producing a current flow from a collector to emitter of transistor 36 proportional to light impinging upon photo diode 36. The collector of photo diode 36 is connected via three kilohm resistor 90 to a five volt power supply line 86. The emitter of photo diode 36 is connected via a second resistance 92 to a ground voltage. A one microfarad capacitor 94 is
10 coupled between the collector of transistor 36 and ground to provide voltage stability to the node coupled to the collector of transistor 36. Current flow through transistor 36 creates voltage at the emitter of transistor 36 creating current flow through a one microfarad capacitor 94. This current flow creates voltage at the inverting input of operational amplifier 96. A shunt circuit
15 including a 470 picofarad capacitor 98 and one megaohm resistor 100 are connected to the noninverting input of amplifier 96 to provide a shunt path for current generated in this manner.

The noninverting input of amplifier 96 is connected to a reference voltage at a node located between a 470 kilohm resistor 102 and a
20 27 kilohm resistor 104. As a consequence, the reference voltage applied to the noninverting input of amplifier 96 is approximately 270 millivolts.

